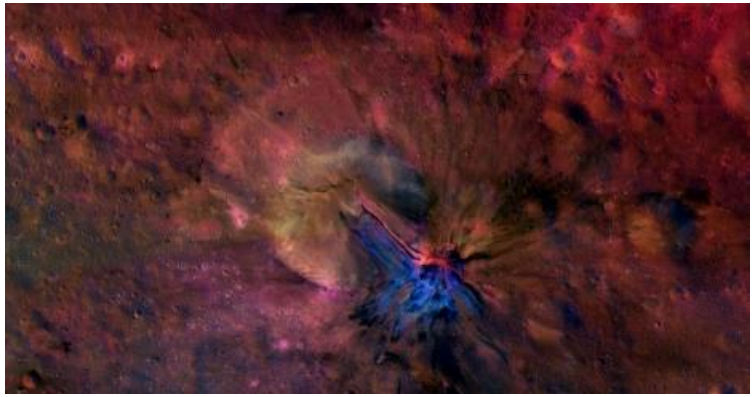
# Space Missions Cost Estimation in TruePlanning®

*Arlene Minkiewicz*
*Chief Scientist, PRICE Systems LLC*
*Arlene.minkiewicz@pricesystems.com*

# Agenda

- Space Missions Model Overview
- Introduction to TruePlanning®
- Framework Orientation
- Space Mission Cost Objects
- Space Missions Model in Use



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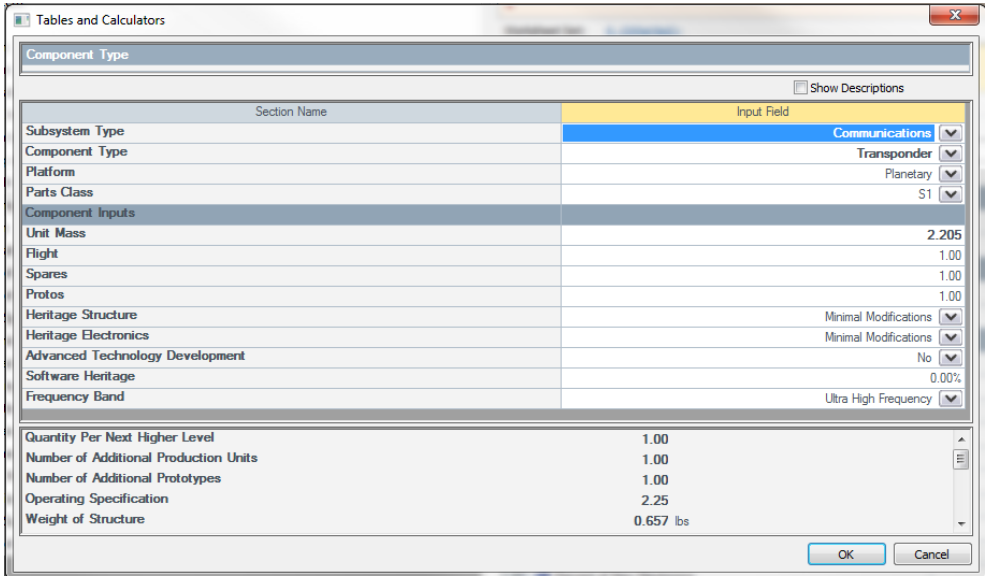
# Space Missions Model Overview

- Cost estimating for Formulation through Implementation for robotic Earth and Space Science Missions
- Methodology used in supporting NASA mission analyses for 25 years.
  - 1989: initially developed to support NASA's Discovery Program
  - Applied to Mars Pathfinder and NEAR
  - 1991: Major modification to incorporate PRICE H
  - Used for NASA's first Discovery AO (Announcement of Opportunity) evaluation in 1994
  - Periodic updates from 1994-2014
  - Updated regularly with data from missions such as Lunar Atmosphere and Dust Environment Explorer(LADEE), Mars Science Laboratory (MSL), Gravity Recovery and Interior Laboratory (GRAIL), etc.

# Space Missions Overview

- Implementation of PRICE TruePlanning® for Hardware specifically tailored for estimation of Space Missions




| Subsystem / Component |
|---|
| **STRUCTURE & MECHANISMS** |
| Primary Structure |
| Secondary Structure |
| Shielding |
| Solar Array Substrate/Structure |
| HGA Structure |
| Electronics Boxes |
| Mechanisms |
| Motor/Actuator |
| Booms |
| **ROBOTIC ARM** |
| Robotic Arm - Limb |
| Robotic Arm - Joint/Actuator |
| **THERMAL CONTROL** |
| MLI, Paints, Coatings |
| Heaters, RHUs, Thermostats |
| Radiators/Louvers |
| Heat Pipes |
| Cryocooler |
| **PROPULSION** |
| Propulsion Lines/Valves/Fittings |
| Pressure Regulator |
| Tanks |
| Thrusters |
| **ELECTRIC PROPULSION** |
| Ion Thruster * |
| Power Processing Unit * |

| Subsystem / Component |
|---|
| **GUIDANCE, NAVIGATION, & CONTROL** |
| Star Tracker |
| Sun Sensor |
| Reaction Wheel |
| Torque Rod |
| Gimbals |
| IMU-Gyro |
| Actuators |
| Radar Altimeter * |
| **COMMUNICATIONS** |
| Transponder |
| Transmitter |
| Amplifier |
| Misc RF Electronics |
| HGA |
| MGA/LGA |
| Waveguide/Comm Cabling |
| **COMMAND & DATA HANDLING** |
| Command/Data Processing |
| Solid State Memory |
| **POWER** |
| Power Management and Distribution |
| Solar Cells/Electrical |
| Pyrotechnics |
| Batteries |
| Harness |

| Subsystem / Component |
|---|
| **ENTRY & DESCENT** |
| Themal Protection System * |
| Parachute * |
| **OPTICS** |
| Optical Bench |
| Optics |
| Gratings |
| Filter Wheel |
| Optics Filters/Misc |
| **SENSOR SYSTEMS** |
| Laser * |
| Sensors-Detectors |
| CCD Detectors |
| Magnetometer |
| TOF Spectrometer |
| ESA sensor |
| Photodiode |
| Bolometer |
| Ion Source |
| Gamma Sensor |
| Neutron Sensor |
| Dust Detector |
| Readout Electronics |

- Component-Level Cost Estimating Methodology
  - Spacecraft/Instrument component types cover all space subsystem functions
  - Flight Element (Spacecraft) and Instrument Estimates are built up from a user-defined combination of subsystem and component-level estimates
  - Space Mission Component level inputs drive the inputs for the PRICE TruePlanning® model for Hardware

 | 

# Space Missions Overview

- Development Phases:
  - **Design:** these costs come directly from the TruePlanning ®Hardware model
  - **Fabrication:** these costs come directly from the TruePlanning ® Hardware Model
  - **Assembly Integration and Test:** these costs are a function of the Design & Fabrication costs
  - **Launch Operations:** these costs are a function of Design and Fabrication costs
- Project Support Functions:
  - Project Management
  - Mission Analysis
  - System Engineering
  - Safety and Mission Assurance
  - Science/Technology
  - Mission Operation System (MOS)
  - Assembly and Integration Support
  - System Test
  - Ground Support Equipment

*These costs apply to all phases*

***Milestones: ATP → CDR→SIR→Ship***

| WBS | Design | Fab | I&T | Launch Ops |
|---|---|---|---|---|
| 1) Project Management | | | | |
| 2) Systems Engineering (w/ Mission Analysis) | | | | |
| 3) Mission Assurance | | | | |
| 4) Science/ Technology | | | | |
| 5) Payload (w/ details by subsystem) | | | | |
| 6) Spacecraft (w/ details by subsystem) | | | | |
| 7&9) MOS/GDS Dev | | | | |
| 10) System I&T (w/ Ground Support Equip) | | | | |

***Space Missions estimated costs align with the NASA WBS and provide phasing details***

 | 

# TruePlanning® Methodology

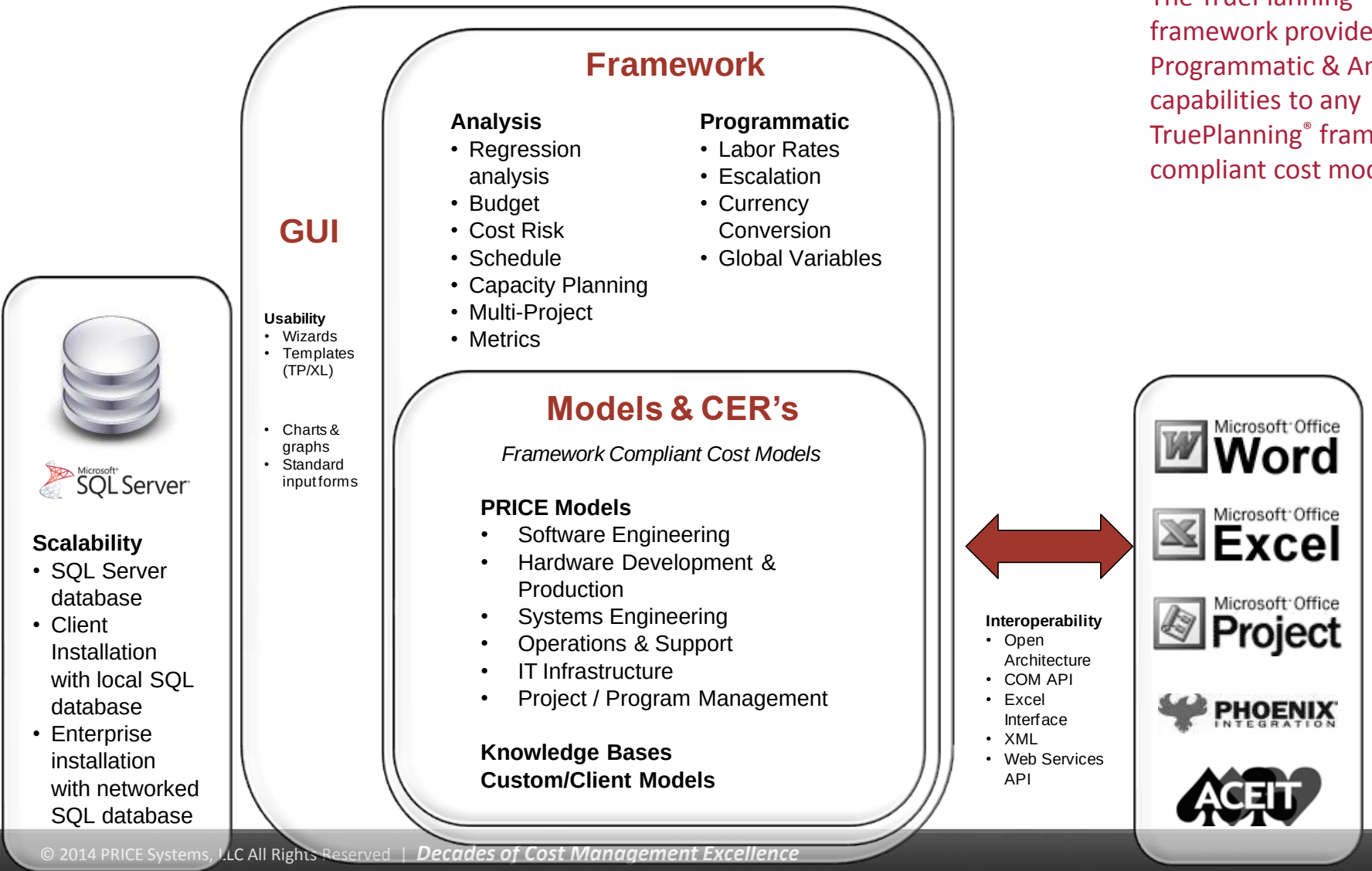
- TruePlanning® is a set of Parametric Models executed using an Activity-Based Costing approach

- Parametric Modeling is:
  - An Operations Research Discipline
  - Relies on …
    - *Mathematical models of real life situations*
    - *The application of these models to new projects and technologies*
  - Relies heavily on historical data
    - *Data is reviewed and important cost drivers are identified*
    - *Regression analysis is used to determine cost estimating relationships*
    - *Results can then be refined with additional data and extrapolated to new projects, technologies and processes*

 | 

# What is the TruePlanning® Framework?

The TruePlanning® framework provides Programmatic & Analysis capabilities to any TruePlanning® framework, compliant cost model.

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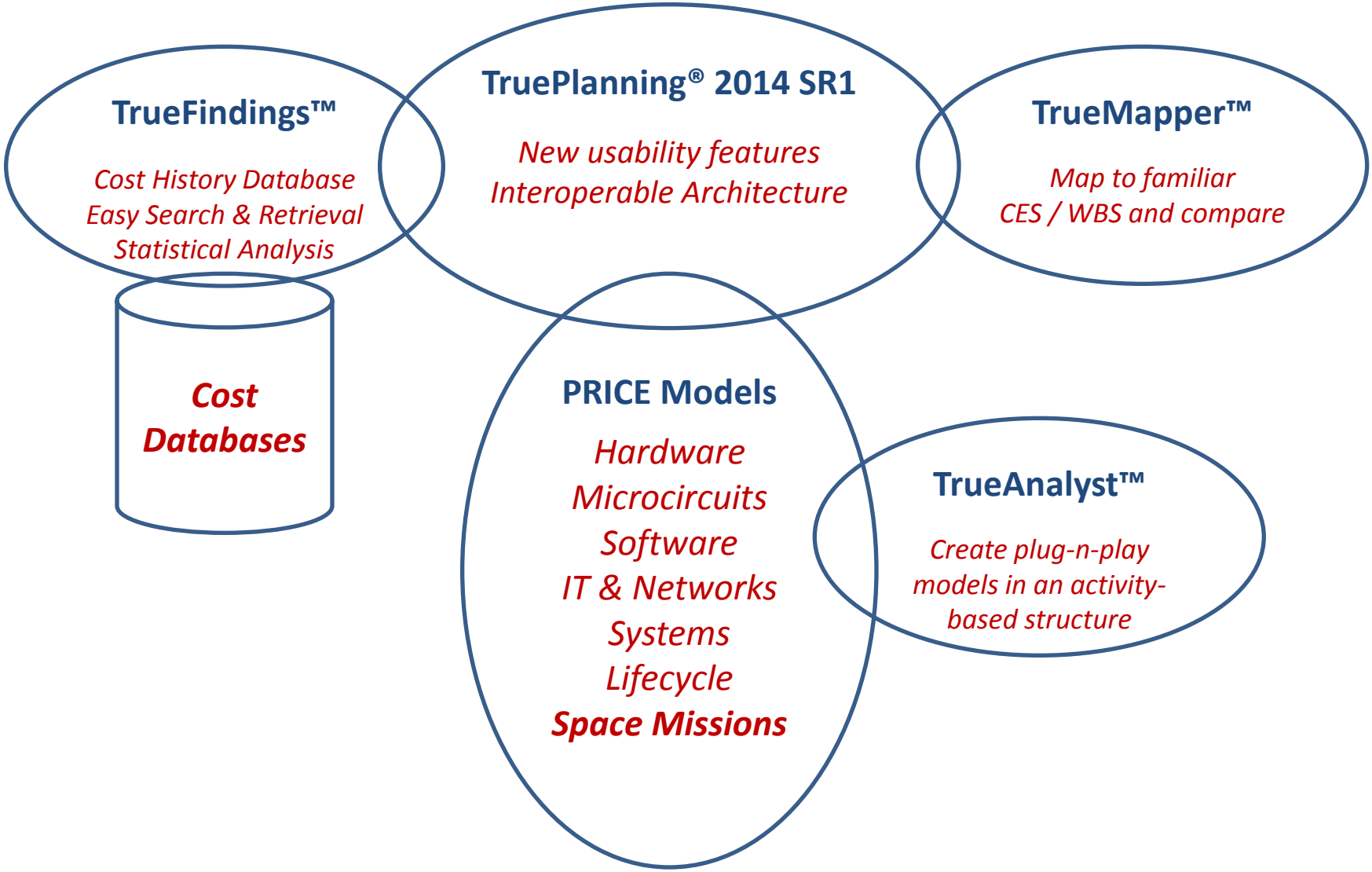
# Space Missions Estimating Environment

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# ABC's of PRICE Parametric Estimation

**TruePlanning® Is a parametric cost engineering solution which estimates costs in support of activity-based costing**


**Cost Object**

- What is produced
- Inputs describe what is being produced - WBS
- Contains activities

**Activities**

The work that is done

- Each type of cost object has different set of activities
- Each activity contains one or more assigned resources

**Resources**

- Anything you spend money on when performing activities
- Labor hours and material dollars

*Effort by Activity & Resource* ✖ *Resource Rates & Activity Adjusters* = **Program Costs by Activity & Resource**

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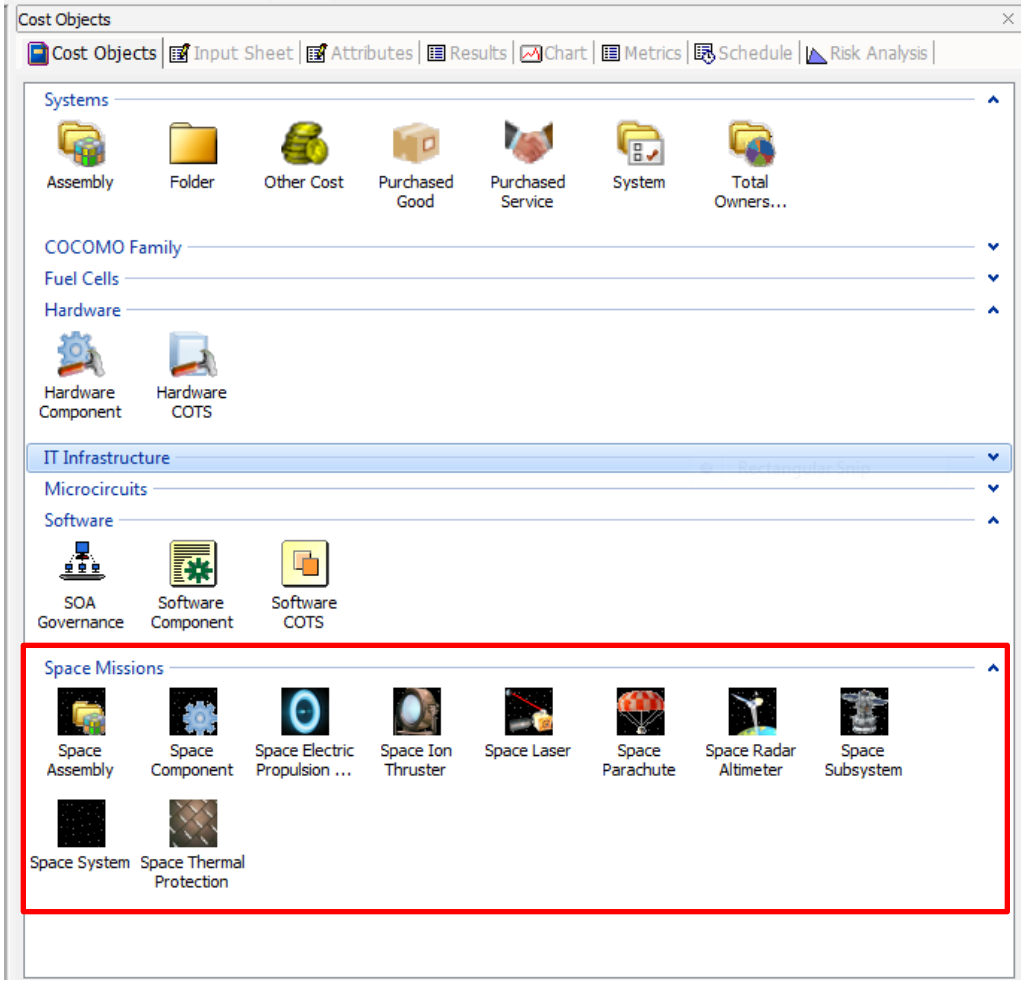
# Cost Objects – PBS Building Blocks

- Cost Models are stored in “Catalogs”
- Each Cost Model contains a series of interrelated cost estimating relationships, an input sheet, activities and resources.

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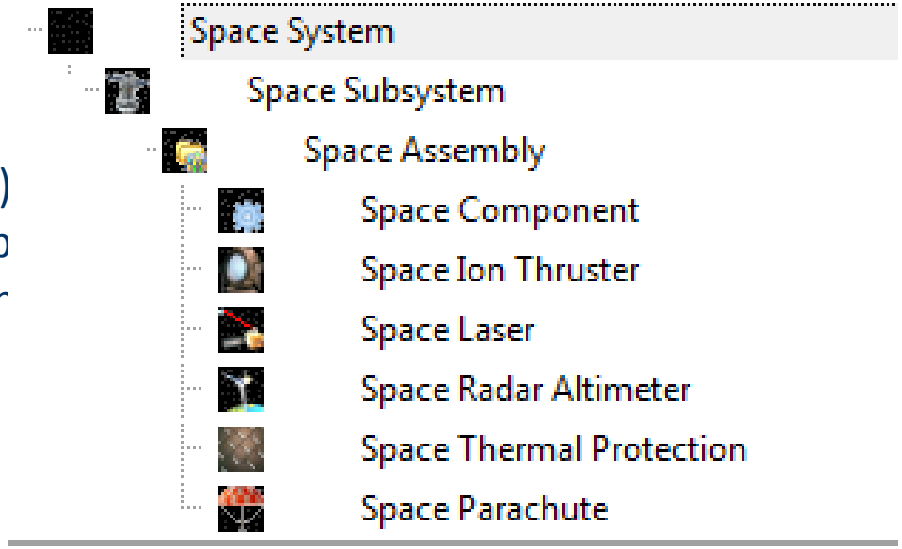
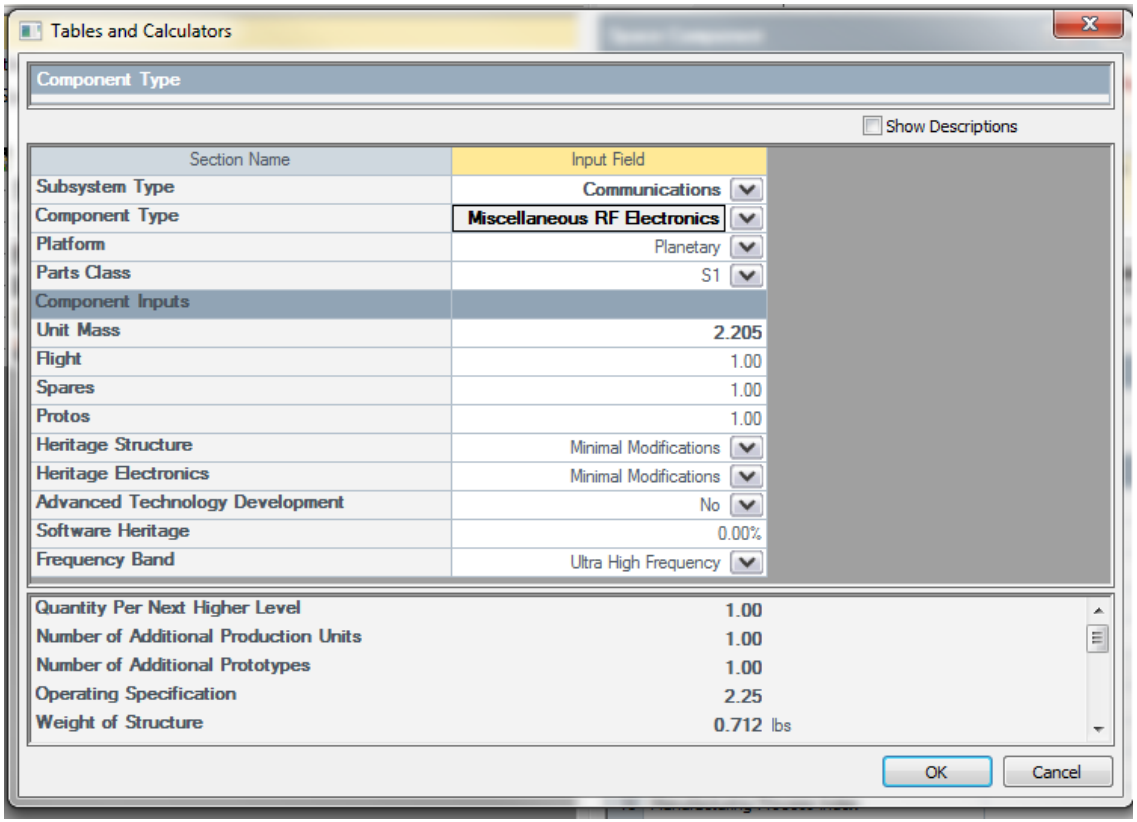
# Space Mission Cost Objects

- Space System
  - Project Support Function Costs for Spacecraft and/or Payload
- Space Subsystem
  - Subsystem-level Integration & Test (I&T) Spacecraft or Instrument subsystem sup to System I&T and Launch Operations th On-Orbit Check-Out
- Space Assembly
  - Roll-up of Subsystem-level Design and Fabrication
- Space Component
  - Design and Fabrication via True Hardware Calculation
- Custom Components
  - Custom CER implementations



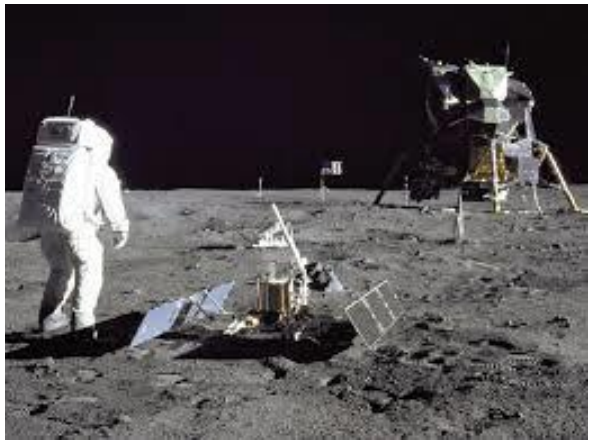
# Space Component Cost Object

- Subsystems
  - Command and Control
  - Communications
  - Guidance, Navigation and Control
  - Optics
  - Power
  - Propulsion
  - Robotic Arm
  - Sensor System
  - Structure and Mechanisms
  - Thermal Control



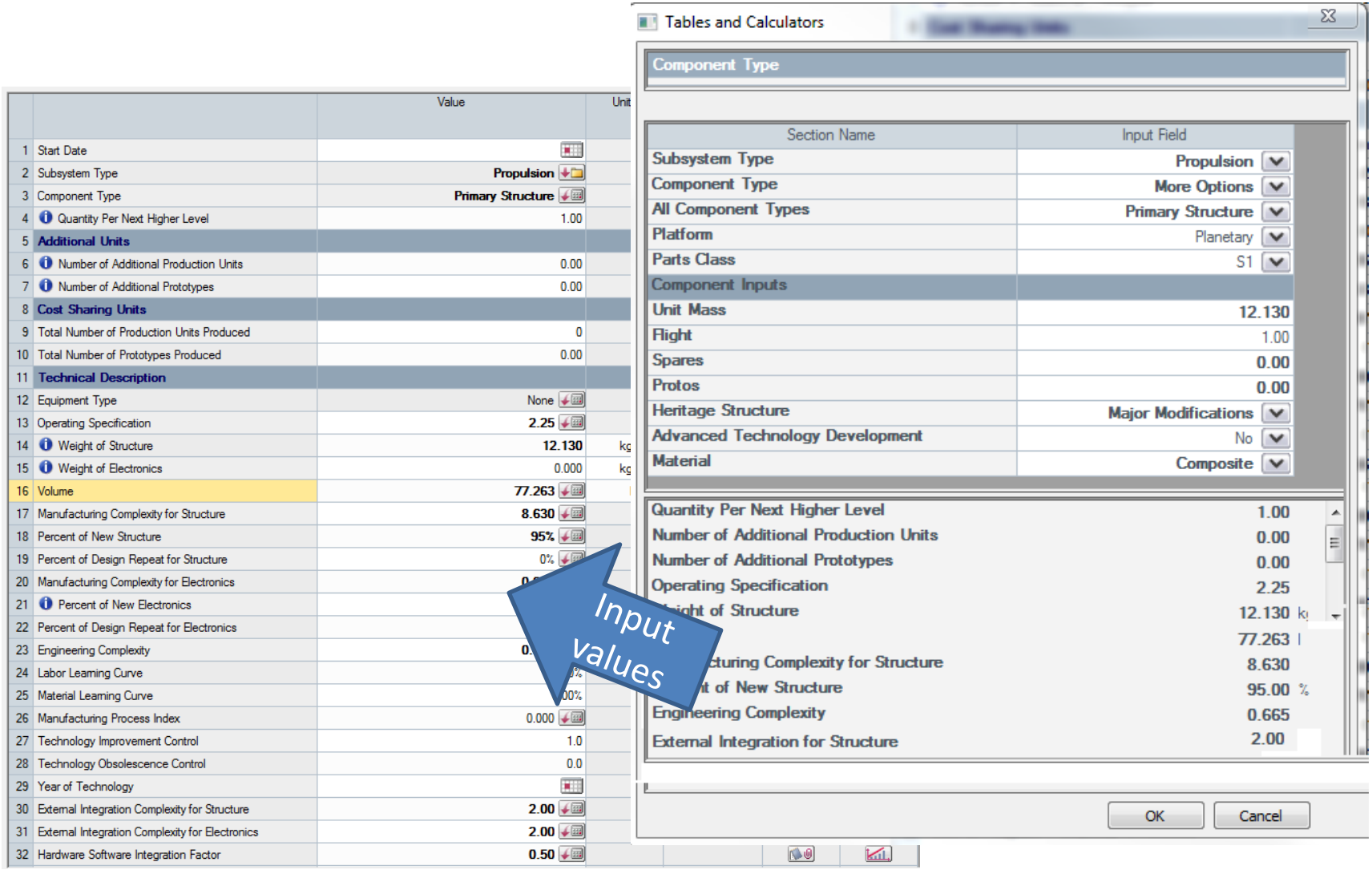
# Space Component Cost Object

- Space Component Calculator inputs generate True H inputs for:
  - Quantity
  - Prototypes
  - Spares
  - Operating Specification (Platform)
  - Weight of Structure
  - Weight of Electronics
  - Manufacturing Complexity of Structure
  - Manufacturing Complexity for Electronics
  - Percent New Structure
  - Percent New Electronics
  - Engineering Complexity



# Space Component Cost Object

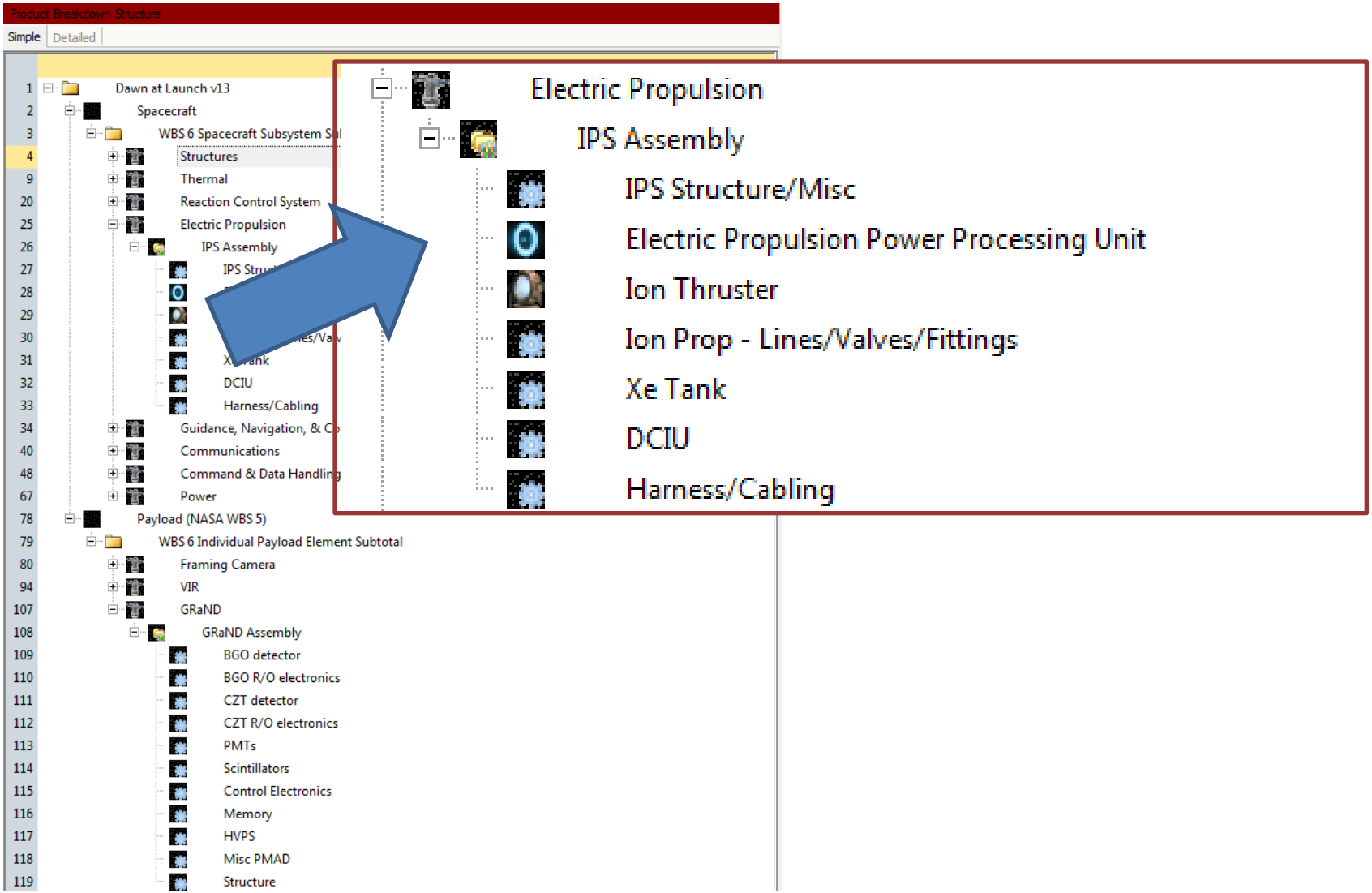


# Space Missions in Use

- Estimate for Dawn Mission at Launch
- The Dawn Mission's goal is to investigate in detail two large protoplanets – Ceres and Vesta  to learn their condition and history
- Estimate is based on technical and cost data collected from the CADRE and through interviews with Subject Matter Experts

# Space Missions in Use

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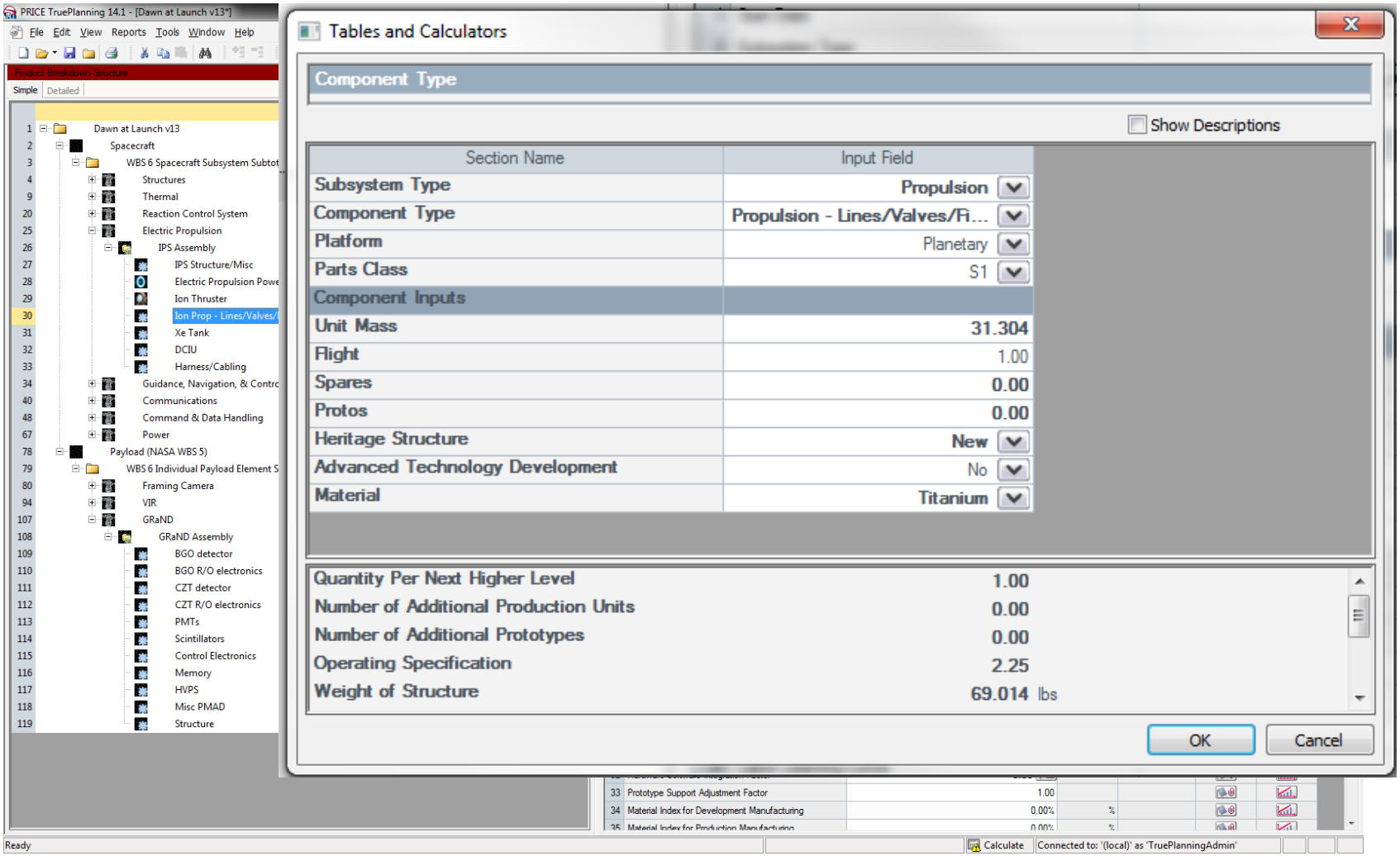
# Space Missions in Use

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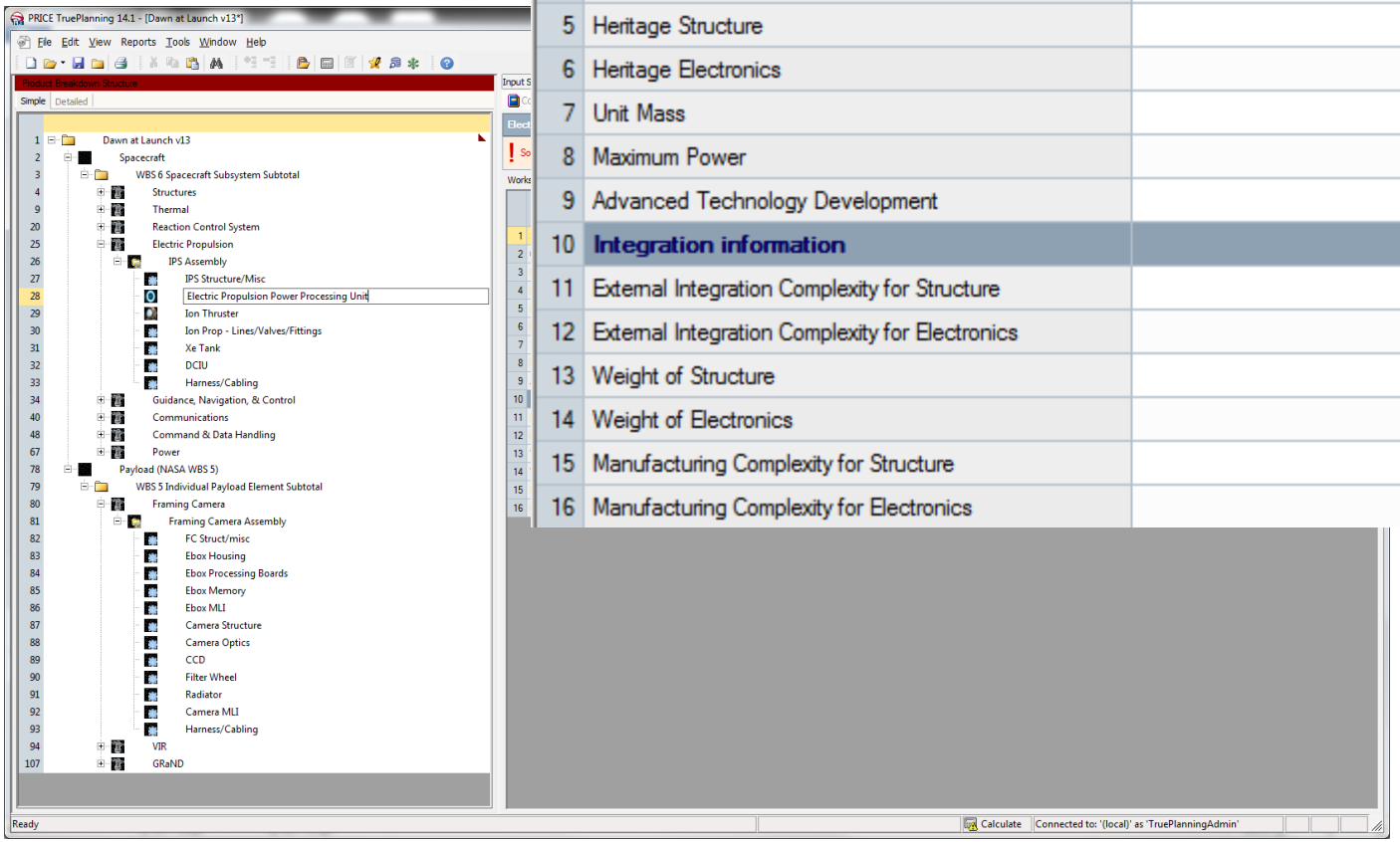
# Space Missions in Use: Custom CERs




| | | Value | Units |
|---|---|---|---|
| 1 | Start Date | 1/2/2003 | |
| 2 | Quantity Per Next Higher Level | 2.00 | |
| 3 | Number of Additional Production Units | 0.00 | |
| 4 | Number of Additional Prototypes | 0.00 | |
| 5 | Heritage Structure | Copy | |
| 6 | Heritage Electronics | Copy | |
| 7 | Unit Mass | 13.90 | kg |
| 8 | Maximum Power | 2.60 | kW |
| 9 | Advanced Technology Development | No | |
| 10 | **Integration information** | | |
| 11 | External Integration Complexity for Structure | 2.00 | |
| 12 | External Integration Complexity for Electronics | 2.00 | |
| 13 | Weight of Structure | 4.200 | kg |
| 14 | Weight of Electronics | 9.700 | kg |
| 15 | Manufacturing Complexity for Structure | 9.210 | |
| 16 | Manufacturing Complexity for Electronics | 10.812 | |

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# Space Missions in Use

**Dawn at Launch v13**

| | | | | |
|---|---|---|---|---|
| Cost: | $390,536,548 | 100.00% | Labor Requirement: | |
| Project Cost: | $390,536,548 | | Project Labor Requirement: | |

| | Costs : Dawn at Launch v13 - [System Folder] Currency in USD ($) (as spent) | Total | Design | Fabrication | Assembly Integration and Test | Launch Operations |
|---|---|---|---|---|---|---|
| 1 | 01. Project Management | 28,299,765 | 6,176,729 | 18,889,125 | 2,712,190 | 521,720 |
| 2 | 02a. Mission Analysis | 4,912,504 | 2,879,336 | 1,022,582 | 643,059 | 367,526 |
| 3 | 02b. System Engineering | 11,189,357 | 4,793,117 | 4,537,971 | 1,594,837 | 263,432 |
| 4 | 03. Safety & Mission Assurance | 16,764,732 | 5,25 | | | |
| 5 | 04. Science/Technology | 6,079,443 | 6 | | | |
| 6 | 07. Mission Operation System | 14,47 | 1,3 | | | |
| 7 | 10a. Assembly and Integration Sup... | 5,2 | | | | |
| 8 | 10b. System Test | 26,323,5 | | | | |
| 9 | 10c. Ground Support | 9,020,553 | 3,2 | | | |
| 10 | Assembler | 15,595,185 | 1,8 | | | |
| 11 | Assembly Integration and Test | 44,224,506 | | | | |
| 12 | Design Engineering | 53,228,453 | 51,4 | | | |
| 13 | Fabricator | 8,884,251 | | | | |
| 14 | Launch Operation | 7,161,229 | | | | |
| 15 | Manufacturing Engineering | 20,595,168 | | | | |
| 16 | Material | 24,836,224 | 5,2 | | | |
| 17 | Non-Recurring Cost | 3,876,541 | 3,8 | | | |
| 18 | Recurring Cost | 2,478,552 | | | | |
| 19 | Support Engineering | 43,698,639 | 29,7 | | | |
| 20 | System Engineering | 4,349,083 | 4,3 | | | |
| 21 | Test Engineering | 17,656,271 | 2,4 | | | |

| | | | Mass (kg) | COST | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Design | Fabrication | AIT | Launch Operations | Total |
| 01 Project Management | | | | $6,176,729 | $18,889,125 | $2,712,190 | $521,720 | **$28,299,765** |
| 02a Mission Analysis | | | | $2,879,336 | $1,022,582 | $643,059 | $367,526 | **$4,912,504** |
| 02b System Engineering | | | | $4,793,117 | $4,537,971 | $1,594,837 | $263,432 | **$11,189,357** |
| 03 Saftey and Mission Assurance | | | | $5,256,690 | $5,968,015 | $4,670,624 | $869,403 | **$16,764,732** |
| 07 Science/Technology | | | | $606,507 | $1,937,752 | $2,950,772 | $584,412 | **$6,079,443** |
| 10a Assembly and Integration Support | | | | $1,313,551 | $5,020,577 | $6,904,756 | $1,240,213 | **$14,479,097** |
| 10b System Test | | | | $1,830,120 | $2,040,194 | $1,178,964 | $174,677 | **$5,223,956** |
| 10c Ground Support | | | | $4,507,513 | $6,137,144 | $14,801,032 | $878,238 | **$26,323,927** |
| And the rest of the Space System Resources similarly mapped | | | | **$3,224,334** | **$3,714,245** | **$1,810,683** | **$271,291** | **$9,020,553** |
| | | | | | | | | |
| 05 Payload (Space System CO) | | | 75.78 | $22,391,180 | $35,864,479 | $20,067,930 | $3,222,012 | 81545600.6 |
| | Framing Camera | | 22.68 | $26,869,416.20 | $43,037,374.46 | $24,081,515.91 | $3,866,414.14 | 97854720.7 |
| | | FC Struct/Misc | 1.33 | $12,283,579.92 | $13,247,447.62 | $5,596,313.68 | $980,273.28 | 32107614.5 |
| | | Ebox Housing | 1.16 | $2,919,207.37 | $3,165,517.16 | | | 6084724.53 |
| | | Ebox Processing Boards | 0.2 | | | | | |
| | | ... | ... | | | | | |
| | VIR | | 25.8 | $10,236,317 | $11,039,540 | $4,663,595 | $816,894 | 26756345.4 |
| | | Optics Module Struc | 12.08 | $2,432,673 | $2,637,931 | | | 5070603.78 |
| | | Cryocooler | 0.5 | $184,994 | $31,735 | | | 216728.216 |
| | | IR Detecter | 0.75 | | | | | |
| | | ... | ... | | | | | |
| | ... | | | | | | | |
| 06 Spacecraft (Space System CO) | | | 645.984 | $21,271,621.16 | $34,071,254.78 | $19,064,533.43 | $3,060,911.19 | 77468320.6 |
| | Structure | | 132.7 | $9,724,500.77 | $10,487,562.70 | $4,430,415.00 | $776,049.68 | 25418528.1 |
| | | Primary Structure | 72.85 | $2,311,039.17 | $2,506,034.42 | | | 4817073.59 |
| | | Secondary Structure | 45.75 | $175,743.94 | $30,147.87 | | | 205891.806 |
| | | Balance Weight | 14.1 | | | | | |
| | | .... | ... | | | | | |
| | | .... | | | | | | |

# Space Missions Model in Action

- PRICE consultants are currently using these models to perform estimates validating several space missions against actuals
  - Validating Space Mission Models vs actuals for 16 different programs
  - Modeled to Level III Breakdown, matching At-Launch Spacecraft and Payload configurations and weights
  - Calculator input values derived from Cost Analysis Data Requirement (CADRE) Part-B data
  - Outputs mapped to NASA WBS categories in alignment with CADRE Part C data
  - Error-bands determined for total, spacecraft, payload and payload instrument costs
  - Burdening and escalation normalized across programs

 

# Conclusions

- The Spacecraft Missions models combine the power of the TruePlanning® framework with a time-tested space specific application of the PRICE Hardware estimating methodology
- One-stop shopping for estimating entire missions including spacecraft and payload
- Models validated by their original creators and long-time users as well as by the PRICE team

 | 

# Questions & Answers

**To submit a question,** please use the **“Questions”** feature located in your control panel, which you can access by clicking on the orange arrow on the right hand side of your screen.

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# Upcoming Events

12 Aug 2014, Herdon, VA | Industry Event

**NASA Cost Symposium**

17 Sep 2014 | Industry Event

**ICEAA SoCal and San Diego Chapters - Workshop**

More details at pricesystems.com/events

View on-demand webinars at pricesystems.com/webinars

# Wrap-up: More Information

Arlene Minkiewicz
Chief Scientist, PRICE Systems LLC
Arlene.minkiewicz@pricesystems.com

## Learn more about TruePlanning® 2014

pricesystems.com/en-us/offerings/trueplanningframework.aspx

Call 1-800-43-PRICE or email: robert.becker@pricesystems.com

## Request more information

pricesystems.com/en-us/requestinfo.aspx

# Thank You!

 | 

# Introduction - TruePlanning®

- TruePlanning® (TP) is an activity-based Resource Consumption Accounting (*RCA*) and Cost Analysis Tool
- TruePlanning® Estimation Framework consists of:
  - ***TrueAnalyst®*** is the application used by PRICE personnel to construct reusable activity-based RCA cost estimating models
  - ***TruePlanner®*** is the application which integrates the TP cost models with schedule and financial information through a robust software architecture and implementation called the TP Framework
  - ***SQL Database*** contains cost models and saved projects

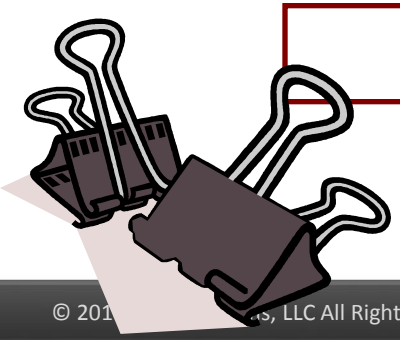
TruePlanning® is an integrated set of cause and effect models. It identifies the primary cost drivers through statistical relationships and applies cost effects through the use of mathematically sound algorithms.

 | 

# Activity-Based Costing Definition

- A special costing model that identifies activities in an organization and assigns the cost of each activity with resources to all products and services according to the actual consumption by each
- A method that measures the cost and performance of process-related activities and cost objects
- Assigns cost activities based on their use of resources, and assigns cost-to-cost objects, such as products or customers, based on their use of activities
- Recognizes the causal relationship of cost drivers to activities
- Measures the cost and performance of process-related activities and cost objects

Source: The CAM-I Glossary of Activity-Based Management, 1990



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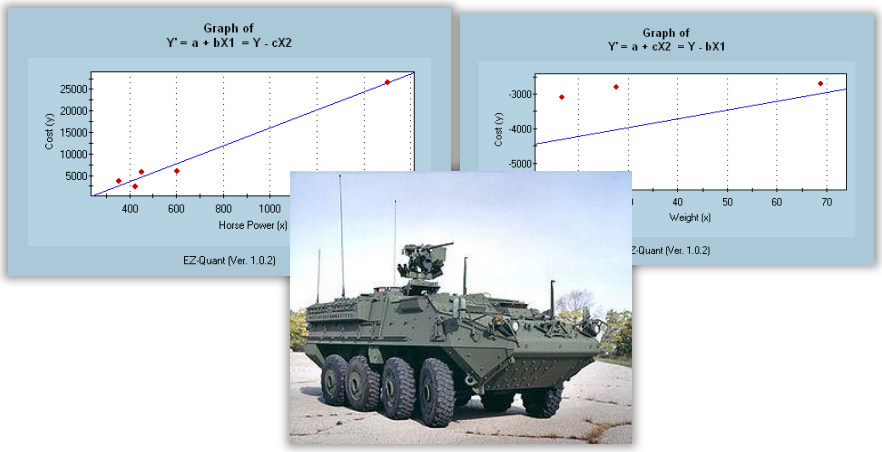
# Estimating Approach Comparison

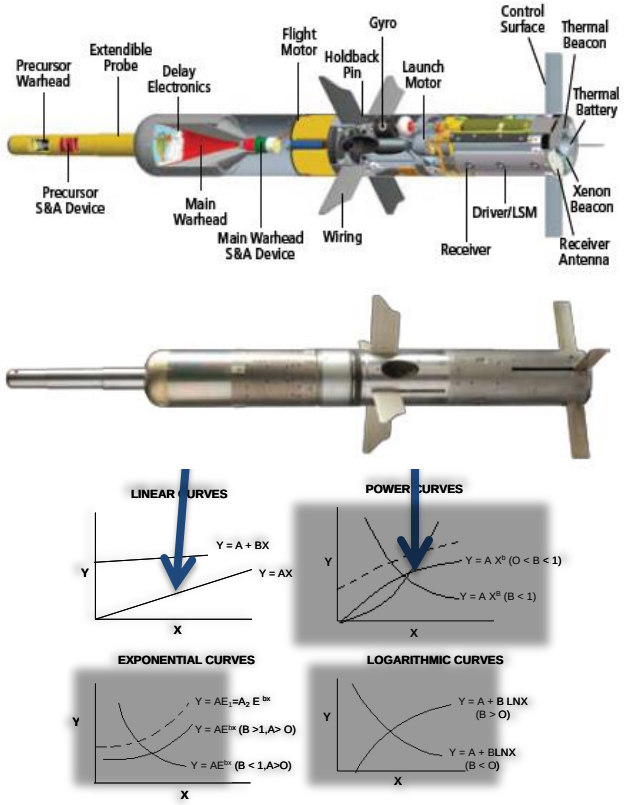
## Traditional Approach

| MDSNAME | Avg Annaul Class IX Cost | Horse Power | Weight |
|---|---|---|---|
| STRYKER | $4,191.54 | 350 | 16.47 |
| PALADIN | $6,559.67 | 450 | 27.5 |
| ABRAMS | $28,417.17 | 1500 | 68.7 |
| BRADLEY | $6,955.52 | 600 | 27.6 |
| FAASV | $3,342.55 | 420 | 26.1 |




**CER: System to Class IX Parts Total Cost**

## TruePlanning® Approach




**CER: Component Parts to Hours To Build**

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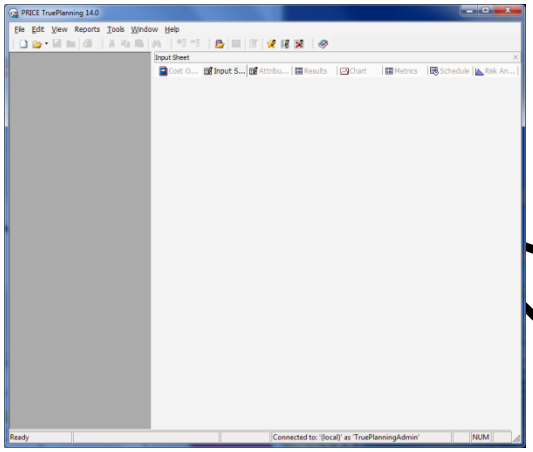
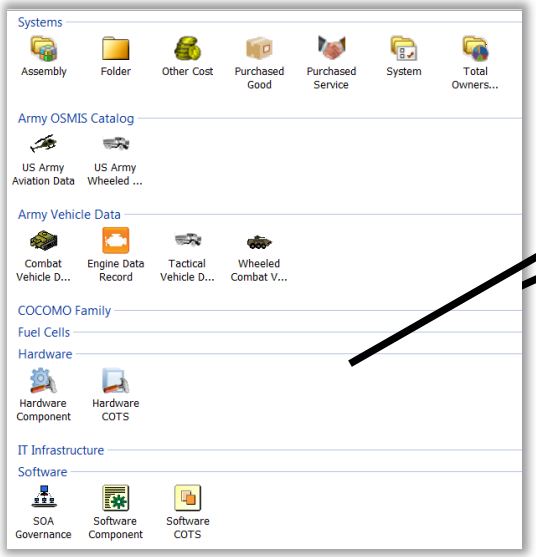
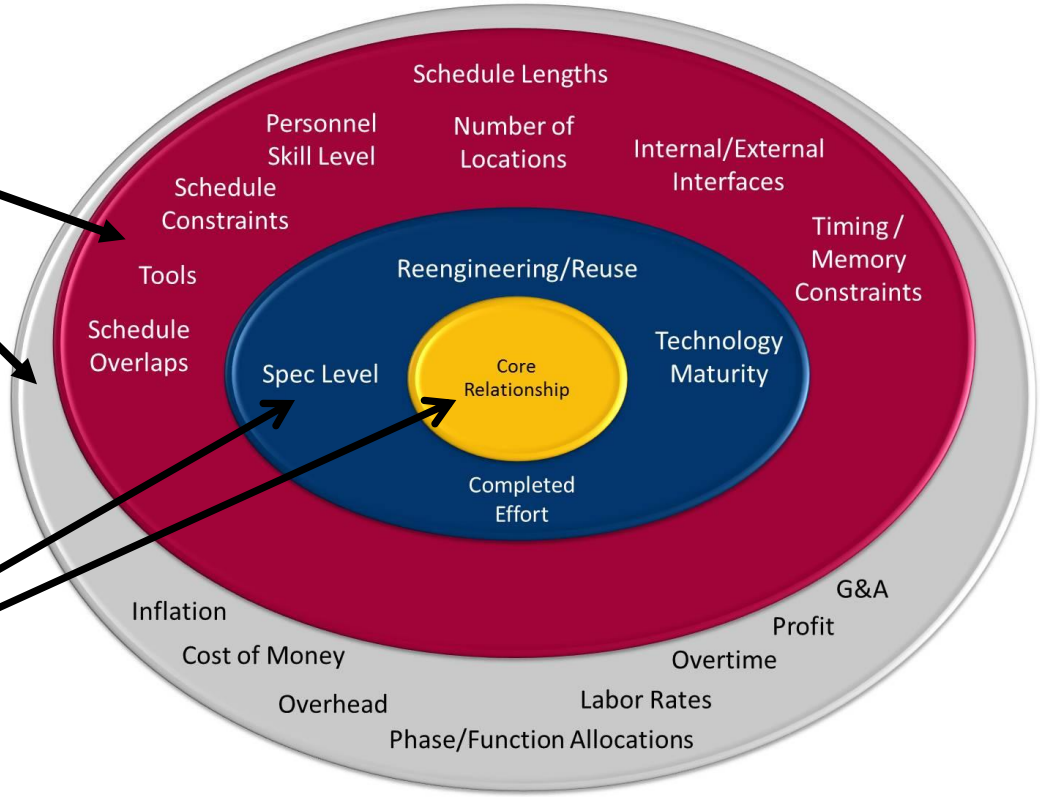
# Framework Orientation

## Cost Research Content Hosted In An Analysis Framework



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# Hierarchical PBS and Integrated Models

- The PBS/WBS is a **hierarchical** method of representing a program with component models
- How the PBS Structure is modeled determines how cost, effort, schedule and risk are reported
- Models can be dragged into the PBS and **renamed** to be more useful or appropriate
- Objects have a Parent/Child relationship